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BIOLOGY AND ECOLOGY OF SEVERAL SPECIES OF CALIFORNIA RANGELAND GRASSHOPPERS

(Orthoptera: Acrididae)

WOODROW W. MIDDLEKAUFF¹

University of California, Berkeley

Studies of the biology and ecology of rangeland grasshoppers have been badly neglected. Much of this neglect can be attributed to the large areas of grasslands involved and, during the era of control by scattering poison baits, the expense and difficulty of control. Westerners have long been aware that grasshoppers on our rangelands have caused economic loss. Like grasshoppers on croplands, those on the range do damage that goes beyond the actual loss of forage. They cut stems and blades, eating only a part of them; they prevent reseeding; they eat grass closer than livestock, and when extremely abundant may injure the crown of the plant so that subsequent growth is retarded; the soil is exposed to the eroding effects of wind and water and they even annoy livestock by jumping in their faces when the latter try to feed.

It was not until the advent of some of the newer insecticides such as aldrin that we realized just how damaging to the range the grasshoppers could be. Workers in the U.S.D.A. have estimated that when grasshopper populations average 6 to 7 per square yard, which I may say is a light infestation, those on 10 acres can eat as much grass as one cow. Many of our infestations in California this past summer were 5 to 10 times this heavy.

As a consequence of the growing awareness of the need for fundamental studies a cooperative regional project was set up with workers in Idaho, Montana, Colorado, Wyoming and California participating. A small sum was allocated to California last August permitting us to begin active participation.

Our objectives were three fold: (1) to make an intensive ecological study of a limited rangeland area inhabited by several of the important rangeland grasshoppers, (2) on the basis of this ecological study, to analyze and evaluate the roles of the various

¹ Presidential address, presented to the Pacific Coast Entomological Society on the occasion of its annual December meeting.

ecological factors (natural enemies, weather, microclimates, vegetation, soil, etc.) in the population dynamics of rangeland grasshoppers in this limited area, (3) to use this information in helping to better understand population dynamics of range grasshoppers, to predict grasshopper damage to rangelands, and to develop more effective and intelligent control measures.

Study areas were selected at the Hopland Range Experiment Station; a foothill area north of Oroville; and a foothill area in the Patterson Pass area of the Livermore hills.

These areas were visited at frequent intervals this past season, field studies and collections were made and this address today is based in part upon these studies.

Much information on species, sex, age composition, parasitism, etc. remain to be secured from the specimens still preserved in alcohol.

A check list of grasshopper species based on a list made by Dr. H. F. Strohecker shows that there are some 187 species in 58 genera occurring in California. At least 50 per cent of these could be classified as rangeland species, those species which normally feed on grasslands and seldom, unless in outbreaks, invade cultivated areas.

In any given area of rangeland it is normal to have a number of different species in close competition with one another. Crop-land species, on the other hand, are only infrequently found competing with several other species.

In all three study areas eight or more species could be found, but the following four were predominant: *Melanoplus devastator*, the devastating grasshopper; *Camnula pellucida*, the clearwinged grasshopper; *Oedaleonotus enigma*, the valley grasshopper and *Dissosteira spurcata*, which has no common name. The following remarks are based upon these four species.

Melanoplus devastator is our most widespread rangeland species and except for localized populations of other species is also most abundant. It is found on the semiarid rangelands in California from Siskiyou county in the north to San Diego county in the south, at elevations from near sea level to over 5,000 feet. It is especially abundant in the oak-grassland plant associations of the Upper and Lower Sonoran life zones where clovers, filaree and annual grasses are dominant.

Outside of California it is recorded from Arizona, Nevada, Utah, Oregon and Washington.

In its nymphal stages this species inhabits much of the range and feeds on the legumes, filaree, bromes and hordeums as long as they remain succulent. When these plants become mature in late May and June the grasshoppers leave the higher parts of the range and congregate in great numbers in swales along roadsides or areas where drought resistant plants such as tarweed, *Hemizonia virgata*; buckthorn weed, *Amsinckia douglasiana*; bluecurls, *Trichostema lanceolatum*; milkthistle, *Silybum marianum*; wild buckwheat, *Eriogonum* spp. and yellow star thistle, *Centaurea solstitialis* can be found. Although they may only feed sparingly upon these latter plants they find them useful as roosting places on which to escape from the high soil-surface temperatures, which often reach or exceed 130°F during the summer.

The nymphs of the devastating grasshopper usually migrate downhill toward more succulent green vegetation, following ravines and lower land toward cultivated crops, often migrating five miles or more during this stage. Heavy movements of nymphs and some adults were taking place this past year by June 13 in the Oroville and Livermore areas as well as in other areas of the state. Grass was dry and shedding seed on hillsides at this date but swales were still green.

The direction of movement is determined by the slope of the land and not by wind direction. Hoppers move downhill with or against prevailing winds as shown by numerous observations made in the study areas. This results in heavy concentrations at the foot of the hills and canyon bottoms.

By the second week in July the species has largely reached the adult stage. The adults are strong fliers and may migrate in thick swarms fifteen or more miles in a single day. Adult movements are less predictable and may be delayed until quite late in the season. For example between July 25 and August 8 a spectacular movement of adult *M. devastator* from the Hopland study area took place. On the latter date it was difficult to collect several dozen adult specimens in an area where they had been extremely numerous less than two weeks previously.

This species is reported by Wilson (1947) to fail to reproduce outside the normal habitat. A residual population, however, remains in the foothills and constitutes the breeding population. A survey in late November in the Livermore hills revealed no *M. devastator* in low areas. Not until we checked halfway up the

Patterson Pass road at an elevation of about 800 feet did we start to encounter *devastator*. Adults were more common on the warmer south and east slopes near the ridge tops.

Dissections have shown that, unlike many of our other economic species that begin to oviposit within ten days after reaching the adult stage, *M. devastator* has a preoviposition period ranging from three to five and a half months, during which no ovarian development or copulation takes place. The breaking of this arrested development apparently is dependent upon the onset of the first fall rains with the concomitant appearance of green grass.

During a five-year period (1951-1956) weather data from Hopland has shown that the earliest date for the first fall rain of 0.5 inch was August 25 and the latest was November 13. Thus oviposition of *devastator* does not usually begin before September, and under conditions of prolonged delay of fall rains may not start until mid-November or even later. Eggs of this species were found in the Oroville area on October 5, 1956 at which time new grass was 1½ inches in height following 0.85 inch of rain. The eggs were on a south facing slope about three inches from the base of a small rock. Fifteen additional areas were examined but no more pods could be found at this date. A survey on November 24, 1957 in the Livermore hills failed to reveal egg pods of this species, however, many were found December 30 in the hills behind Mission San Jose, California.

The egg pods are not laid at random, but are deposited in restricted locations on well-drained hillocks, ridges, banks of ravines and slopes protected from prevailing winds where soil is gravelly or poor. Within these areas a relatively small area may contain many egg pods, with only a few in the surrounding soil.

Many pods are deposited in association with the basal growth of such plants as Russian thistle, milkweed, mustard, tarweeds and others. Some are laid in the soil at the edge or even under rocks if a crevice is present. Still others are laid in the matted roots of filaree or in small, well-drained bare spots.

The eggs begin hatching approximately ten days later in the spring than do those of most other economic species in the same area. This is probably due to the lateness in time of oviposition and in total cumulative heat units following oviposition. The minimum effective temperature for egg development of related species is approximately 60°F.

The hatching period, lasting from late April to late July, ranges from 50–103 days, and is thus much longer than that of other economic species in the same area. In most years it is at least twice as long as that of *Camnula pellucida* or *Oedaleonotus enigma*. Many nymphs of *M. devastator* may still be present when associated species are at their peak of oviposition.

The longevity of adults varies markedly and is dependent on climatic conditions. Winters having relatively high temperatures, with sufficient moisture to produce ample food, increase the length of life. Adults have been reported as late as mid-February. The late season adults become very dark, almost lead colored.

Camnula pellucida occurs very abundantly in California and in many localized areas, especially where grasses are more luxuriant, may outnumber *M. devastator*. This species is found in grasslands of mountain meadows, foothills and valleys throughout cismontane California to elevations exceeding 7,000 feet. Outside our boundaries it is found in the northern tier of states into adjacent Canada and in all the states lying west of the 100th meridian. It is primarily a grass feeder but when in outbreak numbers is very destructive to other types of vegetation such as small grains.

Oviposition usually begins the latter part of July and continues through August. Adults were found copulating July 17 at Oroville this past season. This species differs from other California grasshoppers in that it has definite oviposition areas and according to Wilson (1936) goes back and forth between 10 a.m. and 3 p.m. between these areas and the feeding grounds. These oviposition sites are usually on uncultivated grassy knolls and are small in area and well defined. Those studied by Wilson at Tulake varied from 2 to 20 acres in size. Males attend the ovipositing females and may greatly outnumber the females.

The eggs hatch from early May to the latter part of June.

C. pellucida is migratory in habit both in the immature as well as the adult stages. In some areas it is called the warrior grasshopper because the nymphs march in bands from one field to another.

Oedaleonotus enigma ranges throughout the Pacific Coast, having been reported from California, Oregon, Washington, Idaho, Nevada and Arizona. Its distribution in California is similar to that of *M. devastator* though populations have been more localized.

It reaches its greatest abundance along the eastern foothills of the Coast Ranges.

O. enigma is typically a grassland-foothill species. Eggs are laid from July to October. Hatching occurs in early April usually two to three weeks earlier than *devastator*. Egg laying habitats include rolling foothills, valley slopes and uncultivated gravelly flat land with sparse vegetation. Favored egg-laying spots include around and under rocks, under cover of turkey mullein or adjacent to the basal growth of such weeds as thistles, milkweed, poverty weed and saltbush.

Numerous characteristic egg pods were found in the Oroville area during a survey in early October. Small hummocks only several feet above the general ground level were favored and here between or beside small stones, and especially beneath turkey mullein, oviposition took place.

Only the brachypterous adults have been encountered in the Livermore, Oroville and Hopland areas. The long winged form has been reported from other areas in California.

Dissosteira spurcata occurs in the rangeland areas of California from Tehama County in the north to San Diego in the south and was present in fair numbers at all three study areas. It is also reported from Utah and Nevada. Little is known about its biology, so the following observations will be of interest.

Beginning in early July the males of this species engage in mating flights. A single male can be seen to jump into the air a foot or two above a patch of flattened grass or bare spot. The flight is noiseless for about 5-8 seconds then with a slower wing-beat and the abdomen pointed almost downward he begins to make a characteristic buzzing song which lasts about 20 seconds but may continue for 35. The male then abruptly drops to the ground and makes three or four rasping noises by sharply raising the hind legs and rubbing them against the tegmina. A female or two is usually on the ground beneath the singing male. Males were readily collected by approaching with 15 to 20 feet while they were engaged in the nuptial flight and then scooping them up with an insect net in a quick dash. Mating was not observed.

This past season witnessed one of the heaviest rangeland grasshopper outbreaks since the spectacular one in 1949. Grasshoppers were extremely abundant in the ranges around the Central Valley and caused considerable damage. *Melanoplus devastator* was the

predominant species. It was necessary to treat thousands of acres of rangeland to prevent serious damage to adjacent croplands.

The severity of the grasshopper outbreak can be explained to a certain extent by climatological data for 1956-57. At Hopland, 3.03 inches of rain fell in October and permitted females of *M. devastator* to oviposit over a long period of warm, relatively dry weather in November and December with a total precipitation of less than one inch during the latter two months. Moderate rains totaling 29.4 inches fell during the rainy season permitting good grass growth. Maximum daily temperatures remained below 60°F until the latter part of March. Moderate rains during March, April and May with relatively cool weather held back the egg hatch. During the late May early June hatching period no rain fell to harm the nymphs or permit a disease outbreak.

During the heavy movement out of the Livermore hills the country took on a desolate appearance due to defoliation of many trees, shrubs and grasses. The following is a list of some of the plants heavily fed upon: apricot, fig, privet, *Genista*, *Pyracantha*, *Cydonia*, *Cotoneaster*, cottonwood, *Buddleia*, Persian walnut, *Baccharis*, elderberry, pepper, poison oak, willow, gum weed, mullein, grape, juniper and most of the legumes and grasses. Perhaps the most notable were the few plants not attacked such as *Robinia*, toyon, *Acacia*, Lombardy poplar and elm. These were only lightly fed upon.

Temperature plays an important role in regulating many activities of grasshoppers. A number of observations were made this past season and more extensive ones with the aid of our new mobile laboratory are planned for the future.

Hoppers are quite sluggish when the ground temperature is around 60°F. and can easily be picked up by hand. If they do jump at this temperature they seem unable to do so a second time and can then be captured. Above 70°F. they become quite active and can only be caught then with the aid of a net.

During the heat of the day when ground temperatures in full sun exceeded 110°F. the grasshoppers concentrate in the more grassy areas and around clumps of taller vegetation, such as Harding grass clumps. As temperatures continue to rise the grasshoppers discontinue activity and seek shady spots or climb up grass or weed stems and remain there until late afternoon. Temperature readings taken at Hopland on 24 July showed the

ground temperature to be 131°F. at 2:30 p.m. At this time few hoppers could be found on the ground. Most of them were clinging to grass stems several inches to one foot above ground. Air temperatures taken at the same time as the ground temperatures, showed it to be 29 degrees cooler one foot above the ground. Similar readings beneath the shade of an adjacent oak, where hoppers were numerous showed a ground temperature of 91°F. and only one degree cooler one foot above ground. No hoppers were clinging to vegetation beneath the oak at these temperatures.

After nightfall the ground temperatures are usually warmer than air temperatures, for example at 9:30 p.m. on 24th of July at Hopland the ground temperature was 76°F. while the air temperature was four degrees cooler. As the night progressed the hoppers gradually descended the grass stems and by the following dawn had burrowed into the grass clumps. The ground temperature at 7:15 a.m. was 57°F. while the air temperature was 56. No activity took place at these temperatures.

The commonly accepted technique for determining adult populations by estimating the number of individuals on a number of estimated square foot samples, leaves much to be desired. Adults tend to fly, in many instances while beyond the range of human visual acuity. There is a moving wave of adults preceding the counter. In addition the eye tends to be attracted to a moving object and thus there is a tendency to pick out those square foot areas where hoppers are present and moving and avoiding the areas where none are present. All of these factors tend to give an incorrect estimate of the population.

Several of these difficulties can be overcome by counting adults at night. A wire screened wooden frame, one foot square was constructed. Several nails projecting from the bottom edge prevented it from skidding or rocking. After darkness had fallen and the hoppers had ceased activity the frame was thrown at random in an area where hoppers had been most numerous during the day. Atomized lighter fluid or an aerosol insecticide was then used to agitate the hoppers enclosed beneath the wire mesh which were then counted with the aid of a flashlight. In several areas where these counts were made the cage sample showed far fewer adults than were estimated during the day.

Grasshoppers have many natural enemies. Without the effects of parasites, predators, diseases and adverse climatic factors,

grasshoppers would be much more abundant and outbreaks would be more frequent and severe. Some affect the eggs while others affect the immature and adult stages. Among the more effective enemies in California are Bombyliidae, Meloidae, Sarcophagidae, spiders, rodents and other mammals, birds and diseases. Parker and Wakeland (1957) report that rangeland species suffer far less from egg pod predators than do those species in croplands. The fact that most species of rangeland grasshoppers scatter their egg pods more widely than species of crop grasshoppers, makes it more difficult for predators to find them and may be one reason for the lower percentage of egg pods destroyed in grasslands. The above authors also found predatism to be always highest during those years of greatest egg pod numbers. Another possible explanation of the higher predatism in cropped areas is the fact that Bombyliidae adults frequently gather in large numbers to feed on the blooms of annual plants growing on disturbed ground along fence rows and roadsides and numerous Meloids feed on legumes such as alfalfa, *Melilotus* and composites such as *Hemizonia*.

Wilson (1936) studying *Camnula pellucida* in the Tulake area of California in 1928 found a Bombyliid, *Aphoebantus hirsutus*, to attack up to 62 per cent of the egg pods of this grasshopper and in spots to completely eliminate the threat of an outbreak. I have found, as yet unidentified, Bombyliidae larvae on the egg pods of *O. enigma* at Oroville, but only in very small numbers.

According to MacSwain (1956) the known life cycles of the meloid subfamily Lyttinae, which includes *Epicauta*, indicate that females lay eggs in excavations in the soil. However, observations made in the Oroville area would indicate that this habit does not hold true for all members of the genus. A number of adult meloids were collected feeding upon the flowers of *Hemizonia*, a tarweed. These were identified by Werner as mostly *Epicauta puncticollis* with several *E. californica* also present. These are very common and widespread species in California. According to MacSwain nothing is known about the life cycle of *puncticollis*. Parker and Wakeland (1957) list it as the only meloid egg pod predator known in California. The area where these meloids were found was heavily infested with *M. devastator*. On October 4, 1956 numerous meloid eggs were found on the under surface of a rock

and on the soil beneath. The rock was not resting flat on the ground but was somewhat concave permitting adult beetles to crawl beneath and oviposit.

At least 13 distinct egg masses were found with one mass containing 150 eggs. A total of about 1,500 eggs were present in all stages of development. Some triungulin larvae were hatching at this date and were running rapidly over the surface of the rock. They continued to hatch until October 25th when approximately 1,000 larvae had been collected and preserved in alcohol. Dr. MacSwain identified the larvae as mostly *E. puncticollis* with some *E. californica* present. Dr. Hurd collected eggs of *E. californica* in the Patterson Pass area of Alameda county in November, 1948 and larvae emerged 26 days later. Thus the incubation period is between 21 and 26 days, with the larvae overwintering.

On July 25, 1957, at Hopland in an area of sparse vegetation with sandy soil, a female *Tachysphex tarsatus* Say (det. R. M. Bohart) was observed to attack and subdue a second instar nymph of an oedipodine grasshopper. She pounced upon the nymph which was nearly her size, clinging tenaciously to it while they both struggled on the ground. The grasshopper fighting for its life, the female *Tachysphex* for food for her future offspring. The wasp quickly stung the nymph under the thorax and the hopper immediately gave up the struggle. She paused briefly, placed herself astride the victim, grasped its head with her mouthparts and the abdomen with her hind legs and proceeded to drag the victim over the ground in short flying hops. She was captured during her journey.

Williams (1913) made some careful observations on this species in Kansas and reported that the nest is made in sandy soil, about one and one-half inches long, terminating not quite an inch below the surface of the ground. The tunnel, which is dug before the hunt begins, is left open while the female is sarching for young grasshoppers. It is of comparatively large bore, slightly inclined, and not more than two inches long. As a rule a single nymphal grasshopper suffices for one wasp larva. Williams reported never having seen a nest with more than two hoppers per nest. The female lays an egg on the ventral part of the hopper's thorax and then closes the burrow with the loose soil at the entrance. She then leaves, presumably to repeat the process again and again.

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ZOOLOGICAL NOMENCLATURE: NOTICE OF PROPOSED USE OF THE PLENARY POWERS IN CERTAIN CASES FOR THE AVOIDANCE OF CONFUSION AND THE VALIDATION OF CURRENT NOMENCLATORIAL PRACTICE. (A(N.S.)40)

Notice is hereby given that the possible use by the International Commission on Zoological Nomenclature of its Plenary Powers is involved in applications relating to the under-mentioned names included in Double Part 10/11 of Volume 13 and Part 1 of Volume 16 of the *Bulletin of Zoological Nomenclature* which will be published on 30th December, 1957.

(a) *Application in Part 1 of Volume 16*

- (1) *Calandra* (*Calendra*) Clairville & Schellenberg, 1798, suppression of, in favor of *Sphenophorus* and *Sitophilus*, both Schoenherr, 1838, respectively, in interests of universality of nomenclature; *abbreviatus* Fabricius, 1787 (*Curculio*) and *oryzae*, emendation to, of *oryza* Linnaeus, 1783 (*Curculio*), validation of (Class Insecta, Order Coleoptera) (Z.N.(S.)255).

The present Notice is given in pursuance of the decisions taken on the recommendation of the International Commission on Zoological Nomenclature, by the Thirteenth International Congress of Zoology, Paris, July 1948 (see *Bull. Zool. Nomencl.* 4:51-56, 57-59; *ibid.* 5:5-13, 131).

Any specialist who may desire to comment on any of the